Glycemic index and quality evaluation of little millet (*Panicum miliare*) flakes with enhanced shelf life

Kavita B. Patil · Bharati V. Chimmad · Sunanda Itagi

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Abstract Little millet is a minor cereal crop contains several nutraceutical components. Ready To Cook (RTC) flakes of the millet exhibited higher total dietary fiber content (22.40 %) compared to dehulled grain (15.80 %). One serving (30 g) of RTC flakes provided 2.25 g of protein, 0.13 g of fat, 0.13 g of total minerals, 9.67 mg of iron and zero *trans* fats. The flakes possessed a medium Glycemic Index (GI) of 52.11 ranging from 41.57 to 61.80 among normal volunteers. Glycemic Load (GL) of the flakes was a low of 9.24. The RTC flakes exhibited an acceptability index of 81.11. The flakes possessed a shelf life of more than 6 months with an acceptability index of 67.55, moisture content of 11.82 per cent and Free fatty acid content of 18.02 per cent at the end of sixth month of storage period.

Keywords Little millet · *Panicum miliare* · Glycemic index · Glycemic load · Flakes

Introduction

Millet is a group of small seeded species of cereal crops, widely grown around the world for food and fodder. The group includes millets such as little (*Panicum miliare*), foxtail (*Setaria italica*), kodo (*Paspalum scrobiculatum*), common (*Panicum miliaceum*), barnyard (*Echinochloa frumentacea*), pearl millet (*Pennisetum glaucum* (L.) and finger (*Elusine coracana*) millets. Little millet (*Panicum miliare*) is nutritious and has a significant role in providing nutraceutical components such as phenols, tannins and phytates along with macro and micro-nutrients. It is a fair source of protein (7.70 to

16.50 %), fat (2.45 to 9.04 %), carbohydrates (62.50 to 76.30 %), an excellent source of dietary fiber (15.90 to 18.10 %) with good amount of soluble (3.15 to 5.70 %) and insoluble fractions (10.20 to 14.95 %). Besides, it also contains appreciable amounts of minerals such as iron (9.30 to 20.00 mg/100 g), magnesium (133 mg/100 g) and zinc (3.70 mg/100 g) as revealed by several scientists in the field (Hadimani and Malleshi 1993; Ramulu and Rao 1997 and Itagi 2003). Besides, it also exhibited hypoglycemic, hypolipidemic effects and faecal bulking effects (Ravindran 1991; Kumari and Thayumanavan 1997 and Itagi 2003).

Little millet though nutritionally superior and compares well to staple cereals, the usage is limited due to increased production and availability of preferred cereals (such as rice and wheat) at subsidized prices. Compared to staples the small size of the grain and accidental addition of pebbles and stones while harvesting in fields make it difficult for processing. In addition limited availability of processing units in millet growing area restricts its usage. In turn it creates limited availability of convenience foods of millets compared to staple cereals. Shelf life of dehulled millet is low. Due to high fat content dehulled millets turn rancid early as they undergo autoxidation and get infested by insects. Various processing treatments including blanching, malting, dry heating, acid treatment, popping, etc. decrease the level of antinutrients, improve digestibility and increase shelf life. Utilization of millet for novel product development will help in diversifying their use which will be beneficial for human health. Present study was an effort to convert little millet into a convenient ready to cook flakes and to explore the nutritional benefits and storage quality.

Material and methods

Dehulled little millet were procured in bulk, from local market. The grains were sorted by sedimentation method to

K. B. Patil (✉) · B. V. Chimmad · S. Itagi
Department of Food Science and Nutrition, College of Rural Home
Science, Dharwad, University of Agricultural Sciences,
Dharwad 580 005, India
e-mail: kavita.kotagi@gmail.com

remove the chaff and sandy particles and dried in an oven at $60 \pm 5^\circ\text{C}$ for 2 h. The grains thus processed were stored in cold storage (4°C) for further analysis and processing. Conventional batch processing methods were followed for the development of RTC little millet flakes. The grains were sprinkled with 2 per cent water and tempered grains partially gelatinized by steaming with a pressure of 20 to 24 lbs/psi for 20 min in a boiler. It was followed by air cooling to surface dryness. The grains were then passed through a roller (Manjunath Engineering Works, Gujarat) with a gap of 0.25 mm to press the grains in to flakes. The rolled flakes were thoroughly sun dried to remove excess moisture and stored.

Chemical analysis The nutrient composition of RTC little millet flakes was measured by using standard procedures (AOAC 1990). Protein was assayed by using Kjelplus dx (Pelican); fat by solvent extraction by using petroleum ether in a Socs plus apparatus (Pelican), ash by muffle furnace, micronutrients by using Atomic Absorption Spectrophotometer and moisture analysed at 90 to 110°C . The carbohydrate content was calculated by difference method. The calorific value was derived by multiplying carbohydrate and protein contents by four Kcal and fat by nine Kcal. Dietary fiber was estimated from defatted sample using amyloglucosidase (Asp *et al.* 1983). *Trans* fatty acid content was estimated by using gas chromatographic method (AOAC 1990). Free fatty acid content was estimated by titrating the samples against potassium hydroxide (0.01 N) in presence of phenolphthalein indicator (AACC 1983).

Glycemic index Glycemic index of the RTC flakes was analysed among 10 non diabetic, sedentary and normal women (30 to 35 years old) volunteers who were on overnight fast by following the methods of Wolver and Jenkins (1986). Initially the volunteers were administered with 50 g of glucose along with 200 ml of water as reference food. Later with an interval of 1 week as a wash out period, 50 g of carbohydrate as test food (84 g of flakes) was administered in the form of *Avalakki*. Fasting blood glucose of the volunteers was assessed by using glucometer (Precision I.Q.D). The capillary blood samples were drawn by finger prick method at every half hourly interval during $2\frac{1}{2}$ h period. Blood glucose response curves were plotted for both glucose and test food. The glycemic index was calculated by following formula.

$$\text{Glycemic Index (GI)} = \frac{\Delta \text{Area under glucose curve of RTC } \textit{avalakki}}{\Delta \text{Area under glucose of reference meal}} \times 100$$

Glycemic load (GL) was estimated by multiplying the amount of carbohydrate contained in one serving (30 g) of test meal with GI value of the product, divided by 100 (Salmeron *et al.* 1997).

Sensory evaluation Sensory evaluation of RTC flakes was performed by preparing *avalakki*, a traditional and common breakfast item of North Karnataka. Millet *avalakki* was prepared by using oil (5 %), spices such as mustard, cumin seeds (2 % each), turmeric powder (1 %), salt and chilly. The product was evaluated for sensory characteristics viz., colour and appearance, texture, aroma, taste and overall acceptability by scoring method using nine point hedonic scales. The evaluation was done by ten semi trained panelists of Rural Home Science College, University of Agricultural Sciences, Dharwad, Karnataka, India.

Storage quality evaluation The samples were packed in metalized polyester polyethylene pouches, heat sealed and stored in cardboard boxes at ambient temperature for a period of 6 months. The storage quality was evaluated in terms of sensory quality, moisture uptake, and free fatty acid contents. Sensory evaluation was carried out for the stored product in the form of *avalakki* at monthly interval, whereas, moisture uptake and free fatty acid contents were analyzed initially (0 m) and at the end of the storage period (6th m). Completely randomized design was used to know the difference between mean organoleptic scores of the stored product.

Results and discussion

The proximate composition of little millet is presented in Table 1. The little millet used in the current study contains high amounts of dietary fiber (15.80 %). Staple foods such as wheat and rice were reported to contain much lower levels of dietary fibre of around 8.0 to 9.0 %. Similar high dietary fiber content of little millet (15.9 %) and other millets viz., Foxtail (9.6 %), Proso (13.6 %), Kodo (11.6 %) and Pearl millets (16.2 %) have been documented by Hadimani and Malleshi (1993). Millet exhibited good amounts of protein (7.45 %), total minerals (0.39 mg/100 g), low levels of fat (1.49 %) and energy (303 kcal/100 g). Hence little millet is a nutraceutical grain and has a potential to yield convenience foods in the form of RTC flakes. The data on proximate composition of little millet in the present study is in line with the reports of previous investigators (Ramulu and Rao 1997; Hadimani and Malleshi 1993 and Itagi 2003).

The nutrient composition of RTC millet flakes (Table 2) revealed that the flakes recorded very low fat content of 0.44 % due to formation of amylose-lipid complex owing to lower extractability (Samahy *et al.* 2007) compared to grain (1.49 %). Similar low values were reported in waxy sorghum flakes (0.90 %) by Celis *et al.* (1996) and Saudi wheat flakes (0.83 %) by Ewaidah and Kathani (1992). Total carbohydrates and total mineral contents were 59.10 and 0.44 / 100 g, respectively. The RTC flakes recorded good amount of dietary

Table 1 Nutrient composition of little millet

Nutrients (%)	Little millet	SD value
Moisture	10.00	0.06
Protein	7.45	0.01
Fat	1.49	0.01
Total carbohydrates*	64.87	0.01
Total minerals	0.39	0.01
Total dietary fiber	15.80	0.1
Soluble dietary fiber	5.30	0.1
Insoluble dietary fiber	10.50	0.2
Energy (Kcal)*	303	1.0
Calcium(mg)	22.02	0.01
Iron(mg)	8.18	0.01
Zinc(mg)	3.40	0.1
Manganese(mg)	0.17	0.01

*Computed values

fiber i.e. 22.40 % with major fraction of insoluble fiber (19.20 %) and soluble fraction of 4.20 %. The increase in dietary fiber content in flakes compared to native grain could be attributed to development of resistant starch during moist steaming and cooling cycles performed during processing. It has been demonstrated that heating and cooling cycles significantly increased the resistant starch fractions in wheat (Ranhotra *et al.* 1991). Studies have indicated that iron machines involved in processing lead to high amount of iron in the end products. In the present investigation it was also observed that usage of iron machinery during processing lead

Table 2 Nutrient composition of RTC little millet flakes

Nutrients (%)	RTC little millet flakes		SD value
	Per 100 g	Per serving (30 g)	
Moisture	10.11	3.03	0.01
Protein	7.51	2.25	0.01
Fat	0.44	0.13	0.01
Total carbohydrates [§]	59.10	17.73	0.1
Total minerals	0.44	0.13	0.01
Total dietary fiber	22.40	6.72	0.1
Soluble dietary fiber	4.20	5.76	0.1
Insoluble dietary fiber	19.20	1.26	0.1
Energy(Kcal) [§]	270	81	1.0
Calcium (mg)	22.35	6.71	0.01
Iron (mg)	32.23	9.67	0.01
Zinc (mg)	3.06	0.92	0.01
Manganese (mg)	0.24	0.07	0.01
Trans-fats (%)	0.00	0.00	–

[§] Computed values

to an increased iron content of 32.23 mg/100 g in RTC flakes than grain (8.18 mg/100 g, Table 1). The iron content of flakes is very high compared to native grain, such phenomenon could be observed in elevated levels of iron in rice flakes (20 mg/100 g) than paddy (Gopalan *et al.* 2004). Another feature of significance in the little millet flakes is the zero *trans* fatty acid content recorded in the flakes. *Trans* fats are indicted in several metabolic disorders (Hayakawa *et al.* 2000). However the current product recorded zero *trans* fats. Thus a 30 g serving of RTC millet flakes provided 2.25 g protein, 0.13 g fat, 17.73 g total carbohydrates, 0.13 g total minerals and 6.72 g of total dietary fiber and 9.67 mg of iron. Thus the RTC flakes were nutritionally superior.

Results of assay blood glucose curve for the reference meal compared to test meal among ten normal volunteers is presented in Fig. 1. A steady rise in blood glucose was evident after ingestion of reference and test meals and the peak reaching at 60 min. The mean peak value of the RTC flakes was (141.40 mg/dL) lower than reference meal glucose (168.70 mg/dL). The mean GI values for the RTC flakes ranged from 41.57 to 61.80 and the mean GI was 52.11 (Fig. 2). Millets in general are proved to possess low Glycemic index, values ranging from 54 to 68 for millets like Foxtail, Little, Finger and pearl millet have been reported. It has also been indicated that Jowar recorded a GI of 70 (Mani *et al.*, 1993 and Itagi 2003). It has been demonstrated that heat processing altered the starch content and digestibility of millets (Ugare, 2008). The low GI of RTC millet flakes could be due to formation of resistant starch during partial gelatinization and melting of starch during steaming of grains. It has been revealed that due to shearing of starch during rolling, transglycosidation takes place presumably from attachment of sheared amylopectin branches to other sites, resulting in novel bonds that resist digestion to enzymes (Theander and Westerlund 1987) leading to low amount of glucose release. The GI of RTC flakes (52.11) is relatively lower than those recorded for conventional rice flakes (80.00, www.healthynutritionguide.info), which is commonly used to

Fig. 1 Mean blood glucose response to RTC little millet flakes among normal volunteers

Fig. 2 Glycemic index of RTC little millet flakes among normal volunteers

prepare *avalakki*. Millet flakes could be a better replacement for rice flakes in the daily menu since beneficial for carbohydrate sensitive individuals.

Glycemic load (GL) of the RTC flakes was a low of 9.24, implying lower carbohydrate load per serving (30 g) of the RTC flakes. A similar GL of 8.50 was recorded in rolled oat porridge (www.nutrientdataconf.org).

The compliance report by the volunteers enrolled in the feeding intervention revealed that little millet flakes in the form of *avalakki* was highly acceptable with good sensory qualities (Table 3). The flakes were attractive (7.30). The taste was well accepted (7.20) and the texture was soft and chewable (7.30). The aroma was very good (7.20) and the panelists opined that the product was easy to prepare and highly accepted and adjudged a score of 7.50 for overall acceptability with a mean total score of 36.50 and acceptability index of 81.11. Further the volunteers expressed that the millet flake's *avalakki* elicited high satiety value, a feeling of fullness of stomach for long hours. It was encouraging to learn that the

volunteers were interested to include the millet flakes in their daily menu.

The sensory evaluation of flakes did not show any significant changes throughout storage of 6 months (Table 3). The taste and aroma scores for *avalakki* were 7.20 each on initial storage period which did not change till 5th month of storage (6.60 and 6.40, respectively). However, on 6th the scores decreased gradually (5.70 and 5.60, respectively), but the flakes were acceptable till the end of 6th month. The total mean score decreased from 36.50 to 30.40 whereas, acceptability index from 81.11 to 67.55 at the end of storage. The RTC flakes were free from insects and pests throughout storage. Thus *avalakki* secured acceptable sensory scores with respect to all the scores till end of storage period. A small increase in moisture uptake during storage was observed from 10.11 % (0 m) to 11.82 % (6th m). Free fatty acid content increased from 9.20 % (0 m) to 18.02 % (6th m) (Not given in the table). But there was no perceptible development of off flavors and odors. This enhanced shelf life of millet flakes is appreciable as the hulled millet grains can't be stored more than 3 to 4 months as they turn rancid due to autoxidation and will be infected by insects. The method of processing applied to the product influences the shelf life consistently. The processing technology used in the present investigation is helpful in reducing the fat content and helped in enhancing the shelf life of flakes. Heat processing technique is reported to improve the storage stability of the grains (Bookwalter et al., 1987). The observations in the present investigation are also in agreement with this. The RTC flakes recorded low moisture uptake and free fatty acids, this is beneficial in maintaining the shelf life of flakes. Similar reports were made by Meera et al. (2003) in Pearl millet showing that heat processing was effective in arresting the development of free fatty acids. This was attributed to the effects of heat treatment which removed moisture content from grains and inactivates the activity of lipases, which are mainly responsible for the degradation of

Table 3 Sensory profile^S of *avalakki* of stored RTC flakes

Storage months	Color and appearance	Taste	Texture	Aroma	Over all acceptability	Mean total score	Acceptability index
0	7.30	7.20 ^a	7.30	7.20 ^a	7.50 ^a	36.50	81.11
1	7.20	7.10 ^a	7.20	7.20 ^a	7.50 ^a	36.20	80.44
2	7.40	7.30 ^a	7.40	7.00 ^a	7.20 ^a	36.30	80.66
3	7.40	7.30 ^a	7.20	6.70 ^a	6.70 ^{ab}	35.30	78.44
4	7.00	7.10 ^a	6.90	7.00 ^a	6.30 ^{bc}	34.30	76.22
5	6.60	6.60 ^{ab}	7.20	6.40 ^{ab}	5.60 ^{cd}	32.40	72.00
6	6.50	5.70 ^b	7.40	5.60 ^b	5.20 ^d	30.40	67.55
F value	1.30 ^{NS}	2.78*	0.37 ^{NS}	3.23*	10.01*	—	—
CD	—	0.98	—	0.89	0.81	—	—
SD value	0.37	0.58	0.17	0.57	0.91	—	—

^S Nine point hedonic scale

* $P \leq 0.05$, Values in the same column bearing different superscripts are significantly different

NS Non significant

lipids and liberation of peroxides (Bookwalter et al., 1987 and Lehtinen et al., 2003). Thus the RTC flakes were functionally good, nutritionally superior and possessed a good shelf life.

Conclusion

Little millet is one of the hardiest millets, which thrives well under adverse agro-climatic conditions. Nutritionally little millet is a superior grain with good amounts of macronutrients and dietary fiber. Processing little millet into flakes will not only add convenience while cooking but also indicated potential benefits of medium Glycemic index and no *trans* fats with good shelf life. Hence it could be worthy addition to one's diet as healthy food. However, there is scope to explore the potential benefits of little millet flakes in the management of metabolic disorders through long term feeding interventions.

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